(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 August 2001 (23.08.2001)

PCT

(10) International Publication Number
WO 01/60180 A1

(51) International Patent Classification[7]: A23L 1/36

(21) International Application Number: PCT/US01/04607

(22) International Filing Date: 13 February 2001 (13.02.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/182,446 15 February 2000 (15.02.2000) US

(71) Applicant *(for all designated States except US)*: **LIPOGENICS, INC.** [US/US]; 2425 East Camelback Road #650, Phoenix, AZ 85106 (US).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **LANE, Ronald, H.** [US/US]; 14624 North Seventh Place, Phoenix, AZ 85022 (US).

(74) Agent: **ROSE, Bernard, F.**; Lyon & Lyon LLP, 633 West Fifth Street, Suite 4700, Los Angeles, CA 90071-2066 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 01/60180 A1

(54) Title: ENZYMATIC PROCESSING OF RICE BRAN TO PRODUCE EDIBLE PRODUCTS

(57) Abstract: This invention relates to novel processes for treating rice bran utilizing enzymatic digestion to separate the constituents of rice bran. These processes advantageously bypass several expensive, time-consuming and potentially hazardous conventional rice bran processing steps. The processes of this invention may be used to produce a variety of useful and valuable rice bran-derived products, including rice bran oil, rice bran fiber, rice bran protein and rice bran juice.

ENZYMATIC PROCESSING OF RICE BRAN TO PRODUCE EDIBLE PRODUCTS

TECHNICAL FIELD OF THE INVENTION

This invention relates to novel processes for treating rice bran. The processes of this invention utilize aqueous enzymatic digestion to separate the constituents of rice bran.

RELATED APPLICATIONS

This application is related to and claims priority from provisional patent application serial no. 60/182,446.

BACKGROUND OF THE INVENTION

Rice bran is the outer layer on brown rice. It gives brown rice its color and nutty flavor, and is an excellent source of protein, vitamins and minerals, oil and fiber. Rice bran is used as an ingredient in cereals and mixes, and in vitamin concentrates. Also, its oil has been shown to effectively reduce cholesterol in the blood, and can be used as a high quality cooking oil since it is stable at high cooking temperatures.

Conventional processing of rice bran typically follows a multi-step procedure that generates undesirable waste products and tends to degrade certain constituents of the rice bran. Specialized equipment is required for these processing steps, often making the overall process quite expensive. In addition, many of these conventional processing steps are arduous and time-consuming, and also produce large volumes of waste effluent and low value defatted rice bran.

Accordingly, there remains a need for new processes for treating rice bran that can generate multiple food grade and value-added ingredients, including protein, soluble fiber, aqueous-soluble micronutrients and high grade edible oil, without the disadvantages of conventional rice bran processing.

SUMMARY OF THE INVENTION

The novel processes of this invention meet the unmet need for improved rice bran processing technology. By utilizing aqueous enzymatic digestion to separate the constituents of rice bran, the novel processes of this invention bypass several expensive, time-consuming

and potentially environmentally damaging conventional rice bran processing steps. The processes of this invention may be used to produce a variety of useful and valuable rice bran-derived products, including rice bran oil, rice bran fiber, rice bran protein and rice bran juice.

The processes of this invention include treating a rice bran slurry with an enzyme(s) and then separating the enzymatic products into at least an oil phase, an aqueous phase and a solid phase. It is an objective of this invention that the products of these three phases are edible without further treatment. The processes of this invention also include purifying the oil phase. Furthermore, the processes of this invention include separating the aqueous phase into a recyclable water product and a rice bran juice concentrate, and separating the solid phase into a rice bran fiber product and a rice bran protein product. It is also a further objective that the recyclable water product, the rice bran juice concentrate, the rice bran fiber product and the rice bran protein product are edible without further treatment. Other objectives of this invention will be apparent from the detailed description of the invention that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flowchart depicting the processes of this invention.

DETAILED DESCRIPTION OF THE INVENTION

As used herein, the following definitions apply (unless expressly noted to the contrary):

"Edible" refers to matter that may be consumed by humans without significant deleterious health consequences.

"Rice bran" refers to the outer layer of brown rice. The processes of this invention preferably use raw rice bran. However, dried rice bran, stabilized rice bran or defatted rice bran may be used.

"Defatted rice bran" refers to rice bran that has undergone a process such as pressing (e.g., by an expeller press) to remove a significant portion of the oil from the rice bran.

"Effective particle size" refers to rice bran having an average particle size that enables the enzyme(s) to catalyze the necessary chemical reactions of the invention. "Effective quantity of water, duration, pH and temperature" refer to the values of these substances or conditions where the enzyme(s) is able to perform the necessary chemical reactions of the invention. Furthermore, in the processes of this invention, individual values of particle size, amount of water, duration, pH and temperature should be considered in relation to the values of the other treatment parameters, including the amount and nature of enzyme being used. Although this application provides guidance as to how such values should be evaluated, and sets forth particular values for certain preferred processes of this invention, it is well within the skill of the art to alter the conditions and select other appropriate parameters without undue experimentation. When no specific values are indicated, a value representing an effective parameter is to be presumed.

"Rice bran slurry" refers to a mixture of rice bran and water.

"Enzyme" refers to a type of protein molecule that acts as a biochemical catalyst.

"Enzymatic product slurry" refers to a mixture of rice bran-derived products obtained as a result of the enzymatic treatment of rice bran.

"Oil phase" refers to a product obtained by separating the enzymatic product slurry. Although this phase may contain solutes, particulate matter and water, it contains less of these substances than the solid phase and the aqueous phase. The "oil phase" primarily contains edible oil.

"Aqueous phase" refers to a product obtained by separating the enzymatic product slurry. Although this phase may contain solutes (e.g., protein molecules), particulate matter and oil, it contains less of these substances than the solid phase and the oil phase. The "aqueous phase" contains at least edible rice bran juice and recyclable water.

"Solid phase" refers to a product obtained by separating the enzymatic product slurry. Although this phase may contain some liquid when isolated, it contains less liquid (i.e., water or oil) than the aqueous phase and the oil phase. The "solid phase" contains at least edible rice bran fiber and rice bran protein.

"Purifying" refers to the process of removing some, if not all, impurities from a substance. After purification, some impurities may remain.

"Recyclable water product" refers to a product obtained by separating the aqueous phase. Although this product may contain some solutes, particulate matter, or oil, it contains less of these substances than the rice bran juice concentrate. The "recyclable water product" is primarily water of a quality (dictated by industrial efficiency and environmental regulatory standards) that may be combined with rice bran in order to form the rice bran slurry. Used in this way, it results in pollution abatement by reducing or eliminating an effluent (waste) stream.

"Rice bran juice concentrate" refers to a product obtained by separating the aqueous phase. This product is a combination of at least water, and rice bran protein. Depending on which process is used to separate the aqueous phase, the "rice bran juice concentrate" may also contain constituents that produce a sweet and/or fragrant quality. When the rice bran juice is used as a ready-made beverage, these later qualities are especially desirable.

"Rice bran fiber product" refers to a product obtained by separating the solid phase. Although this product may contain oil, water, and rice bran protein product, it primarily contains rice bran fiber (e.g., cellulose) which remains undissolved during an alkaki extraction procedure.

"Rice bran protein product" refers to a product obtained by separating the solid phase. Although this product may contain oil, water, and rice bran fiber product, it primarily contains protein molecules.

"Vacuum drying" refers to a procedure that removes moisture from a rice bran product by heating the rice bran product at a temperature greater than ambient temperature, and at a pressure less than normal atmospheric pressure (101.3 KPa absolute).

"Short path distillation" refers to the procedure of using a short path distillation apparatus that vaporizes a liquid mixture with the subsequent collection of components by differential cooling to condensation.

"About" refers to a range of +/- 5%, with the exception of pH. For example, "about 10 microns" is equivalent to "9.5 microns to 10.5 microns." When used in relation to pH, "about" refers to a range of +/- 0.2. For example, "a pH of about 10" is equivalent to "a pH of 9.8 to 10.2."

"Free fatty acids" refers to fatty acid molecules that have a free carboxyl group, that is they are not glycerol esters.

"Membrane separation procedure" refers to any procedure that in part uses a membrane that is at least permeable for water, but may be impermeable for molecules larger than water such as protein, or carbohydrate molecules.

"Ultrafiltration" refers to a membrane separation procedure that is pressure driven and whose membrane is permeable to water, inorganic salts, and small organic molecules (e.g., glucose), but impermeable to macromolecules (e.g., albumin protein).

"Reverse osmosis" refers to a membrane separation procedure that is pressure driven such that flow takes place from the higher concentration side of the membrane to the lower concentration, and whose membrane is permeable to water and micro-organic molecules (e.g., ethyl alcohol), but impermeable to macromolecules (e.g. albumin protein), inorganic salts, and some forms of non-ionic organic compounds (e.g., fructose).

"Raw rice bran" refers to fresh rice bran (e.g., has not been dried, stabilized or defatted).

"Average particle size" refers to the arithmetic mean diameter of a sample of particles.

"Pectinases" refer to enzymes that catalyze the hydrolysis of pectin.

"Cellulases" refer to enzymes that catalyze the hydrolysis of cellulose.

"Hemicellulases" refer to enzymes that catalyze the hydrolysis of hemicellulose.

"Carbohydrases" refer to enzymes that catalyze the hydrolysis of carbohydrates.

"Gravity phase separation" refers to a procedure for separating phases of a product based upon the specific gravity of each phase.

"Centrifugation" refers to a procedure using centrifuged force to separate phases based upon the specific gravity of each phase.

"Protein separation procedure" refers to any process that separates protein molecules from water, other biomolecules such as lipids, or other protein molecules. For example, the process of this invention may separate protein molecules according to their size, binding specificity, charge, or solubility.

"Protein solubilization procedure" refers to a procedure whereby a liquid containing undissolved protein molecules is treated until the protein molecules are substantially soluble in the liquid.

"Alkali extraction" refers to a procedure using a solution with a basic pH to extract protein molecules from a solid.

"Dilute" refers to a solution concentration of less than five molar.

"Isoelectric precipitation procedure" refers to a procedure whereby the pH of a solution containing dissolved protein molecules is decreased in order to precipitate the protein molecules.

"Stabilized rice bran" refers to rice bran that has been processed or pretreated by heat, enzymes or chemicals to deactivate lipase enzymes that are naturally occurring in rice bran that when activated produce free fatty acids or rancid oil.

Individual preferred values of various process parameters (including, but not limited to, average rice bran particle size, temperature, pH, type of enzyme and enzyme treatment duration) apply individually to particular process steps, but can also be applied in combination with other process steps.

The processes of this invention use rice bran having an effective particle size as the starting material. This starting material can be obtained from raw, dry or defatted rice bran. If defatted rice bran is used, the processes of this invention will yield little rice bran oil.

To obtain raw rice bran, the rice bran is removed from brown rice using conventional methods. As an alternative to raw rice bran, it is also possible to start with stabilized rice bran. Both raw and stabilized rice bran may be readily purchased from retail stores, as well as a variety of commercial vendors.

To promote effective enzymatic digestion, the average rice bran particle size may be reduced by grinding or milling. Reducing the particle size in this manner may facilitate the enzymatic treatment. Typically, the reduction process is performed by using a food grade mill (e.g., a Szego mill). The average particle size for the processes of this invention is preferably between about 0.1 and about 50 microns; more preferably, between about 1 and about 15 microns; and most preferably, between about 5 and about 10 microns. The most favorable

average particle size may depend on the particular process conditions, and can readily be determined by those of ordinary skill in the art without undue experimentation.

The enzymatic treatment is more productive with the addition of water to the rice bran. Water may be combined with the rice bran before, during or after the reduction process. Since heat may be produced during the reduction process, the most preferred embodiment of this invention includes introducing the water prior to the reduction process in order to minimize thermal damage to the heat sensitive constituents of the rice bran (e.g., rice bran proteins). The addition of water to rice bran with an effective particle size results in a rice bran slurry. Preferably, the rice bran slurry comprises about 1 part rice bran to between about 1 and about 20 parts water (w/v); more preferably, about 1 part rice bran to between about 5 and about 10 parts water; and, most preferably, about 1 part rice bran to about 10 parts water. If desired, the water temperature can be adjusted prior to its addition. In a preferred embodiment, the water is used at room temperature or heated prior its addition. Preferably, the water is between about 23°C and about 60°C; more preferably, between about 23°C and 40°C; and, most preferably, at about 35°C.

The temperature and pH of the rice bran slurry may be adjusted to provide effective conditions for enzymatic treatment. Depending on the type of enzyme being used, and other treatment parameters, the pH and temperature may be adjusted before or after addition of the enzyme in order to meet the enzyme supplier's recommendation. In a preferred embodiment the rice bran slurry is heated prior to addition of the enzyme. The temperature of the rice bran slurry is preferably between about 23°C and about 75°C; more preferably, between about 40°C and about 65°C; and, most preferably, at a temperature of about 50°C. In another preferred embodiment, the pH of the rice bran slurry is adjusted prior to addition of the enzyme to between about 3 and about 6.5; more preferably, between about 4 and about 5.5; and, most preferably, to about 4.5. To achieve these reduced preferred pH values, any suitable acid may be used. The preferred acids for this purpose are food grade acids, such as food grade phosphoric acid.

Once the rice bran slurry has been prepared, it is subjected to enzyme treatment. There are several types of commercially available enzymes that can be used effectively in the processes of this invention. Typically, these enzymes are those recommended by their

manufacturers to degrade cellular structures of plant materials, such as the cell wall tissues that contain the rice bran oil (e.g., cellulose and hemicellulose.) Individual enzymes may be used alone or combined with other effective enzymes to produce a particular desired result. Preferred types of enzymes for use in the processes of this invention include, pectinases, carbohydrases, cellulases, hemicellulases and combinations thereof. A combination of pectinases, carbohydrases, cellulases, and hemicellulases is particularly preferred. Specific enzymes for use in the processes of this invention include Pectinex 3xL (a pectinase), SP-249 (a carbohydrase), Celluclast 1.5L (a cellulase) and Gamanase (a hemicellulase). These four particular enzymes are available commercially from Novo Nordisk (Denmark). Gamanase is a most preferred enzyme for the processes of this invention.

The effective enzyme amount and effective temperature, pH and enzyme treatment time should be selected so as to facilitate enzymatic digestion. Individual values will largely depend on the type of enzyme being used and the values set for other enzyme treatment parameters. The enzyme manufacturers typically provide considerable guidance in this regard. In a preferred embodiment, the amount of enzyme is about 0.1% to about 5% of the rice bran by weight; more preferably, about 1% to about 3%, and most preferably, about 2%. The enzymatic treatment can be carried out in any suitable vessel (e.g., an agitation tank). The preferred enzymatic treatment duration is equivalent to the time when the oil yield of the process is equivalent, or almost equivalent, to the oil content of the rice bran. Depending on the treatment parameters and the type of enzyme(s), typically the enzyme treatment duration will be between about 3 and about 36 hours. Preferably the treatment duration will be between about 5 and about 30 hours; more preferably, between about 7 and about 24 hours; and, most preferably, about 20 hours. During the treatment time, there may be a period of agitation followed by a period of non-agitation (which can take place in the same or a different vessel, such as a settling tank). For example, once the enzyme is added, the enzymatic slurry may be maintained at an elevated temperature (e.g., about 50°C) for about 5 hours with agitation, followed by about 15 hours of non-agitation at the same temperature. During the enzymatic treatment, the rice bran of the rice bran slurry is degraded into its constituent parts, resulting in the enzymatic product slurry. At this time, the oil yield of the enzymatic product slurry is monitored in order to assess the progress of the treatment. Once

the oil yield of the enzymatic product slurry is close to the oil content of the rice bran starting material, the treatment is discontinued.

Following enzyme treatment, the components of the enzymatic product slurry can be separated. Although many separation techniques can be used for this portion of the process, gravity phase separation is preferred (e.g., gravity settling or centrifugation). Most preferably, separation is performed by centrifugation. The centrifuge parameters may be readily determined by those of ordinary skill in the art. An industrial centrifuge will likely be effective with a setting of 3000-6000 X g. Using a laboratory centrifuge, on the other hand, it has been found that using an IEC fixed head rotor at about 9000 X g is effective. At least three phases should result from the separation procedure: (1) a solid phase, (2) an aqueous phase, and (3) an oil phase. The efficiency of the separation procedure is analytically determined by the cross-contamination of the phases. The separation procedure may also produce an emulsion phase. It is an object of this invention to reduce or eliminate the existence of this phase. Typically, the emulsion phase contains a mixture of oil and water that is stabilized by soluble surfactive proteins. By heating or adding an acidic solution to the emulsion layer the layer is separated into oil and water. The resultant aqueous and oil layers can then be added to the previously obtained aqueous and oil phases, respectively. The following sections detail further characterization and treatment options for each of the three primary phases that are separated from the enzymatic product slurry.

Oil Phase

The rice bran oil in the oil phase is of considerable quality. Since the enzyme treatment is relatively gentle to the rice bran constituents, including the oil, the oil can be consumed without further treatment. For this reason, the rice bran oil obtained is superior to conventional industry produced RBD (refined, bleached and deodorized) rice bran oil as it retains its natural flavor and fragrance. Furthermore, the enzymatic treatment results in a recovery percentage that is comparable to conventional industry procedures.

Although the enzymatic treatment produces high quality rice bran oil, the oil phase may be purified to yield a better product. After the separation of the enzymatic product slurry, the oil phase may have about 2% moisture content. This residual moisture can be reduced through vacuum drying to preferably less than about 1.0 %, and most preferably about 0.1% water by weight. This additional step helps to reduce hydrolysis of neutral triglycerides. Also, the oil phase may be subjected to short path distillation which removes free fatty acids to preferably less than about 2 %, and most preferably about 0.5% of the oil phase by weight. Micronutrients can be recovered by further processing the oil phase.

Aqueous Phase

The aqueous phase obtained from the separation of the enzymatic product slurry retains a pronounced, pleasant rice bran aroma, a somewhat sweet flavor and low viscosity, and may be consumed directly without further treatment. This phase typically contains a high percentage of the protein from the rice bran if the pH of the rice bran slurry was below about 5. The protein is solubilized in the aqueous phase under such conditions.

Although the aqueous phase may be consumed without further treatment, this phase may be separated into at least a recyclable water product and a rice bran juice concentrate. By performing this further treatment of the aqueous phase, the concentration of the protein, as well as other desirable constituents of the aqueous phase, can be increased and retained in the rice bran juice concentrate. Conventional concentration techniques known to those of skill in the art, such as freeze-drying, can be used. Preferably a membrane separation procedure is used, such as ultrafiltration or reverse osmosis, although ultrafiltration may result in a loss of aroma. Reverse osmosis is preferred for industrial-scale processing. It may be desirable to pasteurize the aqueous phase before it is separated, or the rice bran juice concentrate after separation.

It is a further objective of this invention to produce a recyclable water product from the aqueous phase. Typically, the recyclable water product will retain some impurities, such as residual carbohydrate and protein molecules. However, by using the processes of the present invention, the amount of impurities will be reduced and the quality of the recyclable water product will be high enough so that it may be reused. In other words, the recyclable

water product may be used as the input water at the beginning of the process (see Fig. 1). As a result of the in-process recycling of the water used, this invention prevents or reduces the effluent water produced by the enzymatic treatment of rice bran. The potential benefits from this segment of the process include cost savings, reduced legal liability, and improved corporate image.

Solid Phase

The solid phase obtained from separation of the enzymatic product slurry is edible. If desired, however, the solid phase can be further processed to obtain rice bran fiber product and rice bran protein product. To separate these components, any conventional protein separation technology can be used. Preferably, alkali extraction is first used to solubilize the proteins. In this preferred embodiment, the protein molecules of the solid phase are extracted into an aqueous alkali solution at an effective pH, typically between about 9 and about 12.5; more preferably, between about 10 and about 12; and most preferably, between about 11 and about 12. Any effective alkali solution may be used, including sodium hydroxide, and potassium hydroxide. Dilute sodium hydroxide is preferred. Typically, water is first added to the solid phase at a ratio of about 1 part solid phase to about 10 to about 20 parts water (w/v); and preferably at a ratio of about 1 part solid phase to about 15 parts water. Then, the alkali solution is added to raise the pH of the solid phase/water combination to the effective pH. Additional volumes of the alkali solution may be added during the alkali extraction to maintain the pH of the solid phase/water combination at the effective pH. This alkali extraction solubilizes a substantial percentage of the protein in the solid layer. Once the protein has been solubilized, the filtrate (containing the solubilized protein) can then be acidified to precipitate the protein. This isoelectric precipitation procedure is typically carried out using an aqueous acid solution at a pH of between about 4 and about 6; preferably, between about 4 and about 5; and, most preferably, at a pH of about 4.5. The precipitated protein tends to be off-white in color and substantially free from any rice bran aroma. This protein precipitate can be isolated by any conventional method. Centrifugation is preferred.

The separation of the solid phase also results in a rice bran fiber product which has a high plant fiber content. The rice bran fiber product is edible without further treatment, but

may be dried using any suitable methods in order to produce a more commercially viable product. For example, a spray drying method may be used.

Without wishing to be bound by theory, the enzyme or enzymes used in the processes of this invention break down the tissue structure of rice bran such that the oil stored in these structures is released. As a result, the rice bran oil can be effectively separated from the remaining rice bran constituents without harsh, conventional processing steps, such as pressing or volatile solvent extraction. Furthermore, the enzymatic treatment described herein is sufficiently mild to allow for the effective recovery of other rice bran constituents, such as rice bran protein, rice bran fiber and rice bran juice concentrate. As a result, the processes of this invention provide an economical and potentially integrated method for the complete utilization of rice bran.

Although it is an object of this invention that the rice bran-derived products obtained using the processes of this invention can be used as food grade ingredients without further processing, they may also be used in animal feed, or industrial applications. For example, the rice bran oil obtained using the processes of this invention is food grade, and may be incorporated into edible products (such as cooking oil, baking ingredients or flavorizers). Alternatively, the rice bran oil can also be used for industrial applications, such as detergents, soaps, creams and shampoos.

Furthermore, the other rice bran derived products (including rice bran fiber product, rice bran protein product, rice bran juice concentrate and recyclable water product) recoverable using the processes of this invention can also be used directly as food grade material and incorporated into edible products. For example, these rice bran-derived products can be used in a host of nutritious foodstuffs (such as nature bars, drinks and drink mixes). Although many other uses of these products will be evident to those of ordinary skill in the art, the use of rice bran fiber product as a high fiber alternative to bran and other fiber-rich material is of specific interest. Also, since the rice bran protein product recoverable using the processes of this invention has a high protein content, it might be used as an alternative to soy protein. Such applications include, without limitation, meat extenders, processed foods, health foods, sport drink mixes, baby foods and baked goods. Water soluble vitamins and micronutrients can be recovered from further processing of the rice bran juice.

While we have described a number of embodiments of this invention, it is apparent that our basic constructions may be altered to provide other embodiments that utilize the formulations and methods of this invention. Such embodiments are considered within the scope of the invention.

Other embodiments are contained in the following claims.

What is claimed is:

1. A process for producing edible rice bran products comprising:

combining rice bran, with an effective particle size, with an effective quantity of water to produce a rice bran slurry;

treating the rice bran slurry with at least one enzyme for an effective duration and at an effective pH and temperature to produce an enzymatic product slurry; and,

separating the enzymatic product slurry into at least an oil phase, an aqueous phase and a solid phase.

2. The process of claim 1, comprising purifying the oil phase.

3. The process of claim 1, comprising separating the aqueous phase to produce at least a recyclable water product and a rice bran juice concentrate.

4. The process of claim 1, comprising separating the solid phase into at least a rice bran fiber product and a rice bran protein product.

5. The process of claim 2, wherein the purification procedure is vacuum drying.

6. The process of claim 2, wherein the purification procedure is short path distillation.

7. The process of claim 6, wherein the oil phase after purification comprises less than about 0.5% of free fatty acids by weight.

8. The process of claim 6, wherein the oil phase after purification comprises less than about 0.1% of free fatty acids by weight.

9. The process of claim 5, wherein the oil phase after purification comprises less than about 0.5% of water by weight.

10. The process of claim 5, wherein the oil phase after purification comprises less than about 0.1% of water by weight.

11. The process of claim 3, wherein the effective quantity of water is taken from the recyclable water product.

12. The process of claim 3, wherein separating the aqueous phase is performed using a membrane separation procedure.

13. The process of claim12, wherein the membrane separation procedure is ultrafiltration.

14. The process of claim 12, wherein the membrane separation procedure is reverse osmosis.

15. The process of claim 1, wherein the rice bran is from raw rice bran.

16. The process of claim 1, wherein the rice bran has an average particle size of about 10 microns.

17. The process of claim 1, wherein the rice bran slurry comprises about 1 part rice bran and between about 1 to about 20 parts water.

18. The process of claim 1, wherein the rice bran slurry comprises about 1 part rice bran and between about 5 to about 10 parts water.

19. The process of claim 1, wherein the pH is between about 4 to about 6.

20. The process of claim 1, wherein the enzyme is at least about 0.1% to about 3% of the rice bran by weight.

21. The process of claim 1, wherein the enzyme is about 2% of the rice bran by weight.

22. The process of claim 1, wherein the temperature is between about 25°C and about 75°C.

23. The process of claim 1, wherein the duration is between about 3 and about 24 hours.

24. The process of claim 1, wherein the duration is about 15 hours.

25. The process of claim 1, wherein the enzyme is selected from the group consisting of pectinases, cellulases, hemicellulases, carbohydrases and mixtures thereof.

26. The process of claim 1, wherein the enzyme is a hemicellulase.

27. The process of claim 1, wherein the enzymatic product slurry is separated by a gravity phase separation.

28. The process of claim 27, wherein the gravity phase separation is centrifugation.

29. The process of claim 4, wherein the separation of the solid phase is performed by a protein separation procedure.

30. The process of claim 29, wherein the separation of the solid phase is performed by a protein solubilization procedure.

31. The process of claim 30, wherein the protein solubilization procedure is an alkali extraction.

32. The process of claim 31, wherein the alkali extraction is performed at a pH of about 11 to about 12.

33. The process of claim 31, wherein the alkali extraction comprises using a dilute sodium hydroxide solution.

34. The process of claim 4, wherein the rice bran fiber product is dried to contain less than about 6% water by weight.

35. The process of claim 4, comprising an isoelectric precipitation procedure.

36. The process of claim 35, wherein the isoelectric precipitation procedure is performed at a pH of between about 4 and about 5.

37. The process of claim 4, wherein the rice bran protein product represents at least about 5% of total protein content of the rice bran.

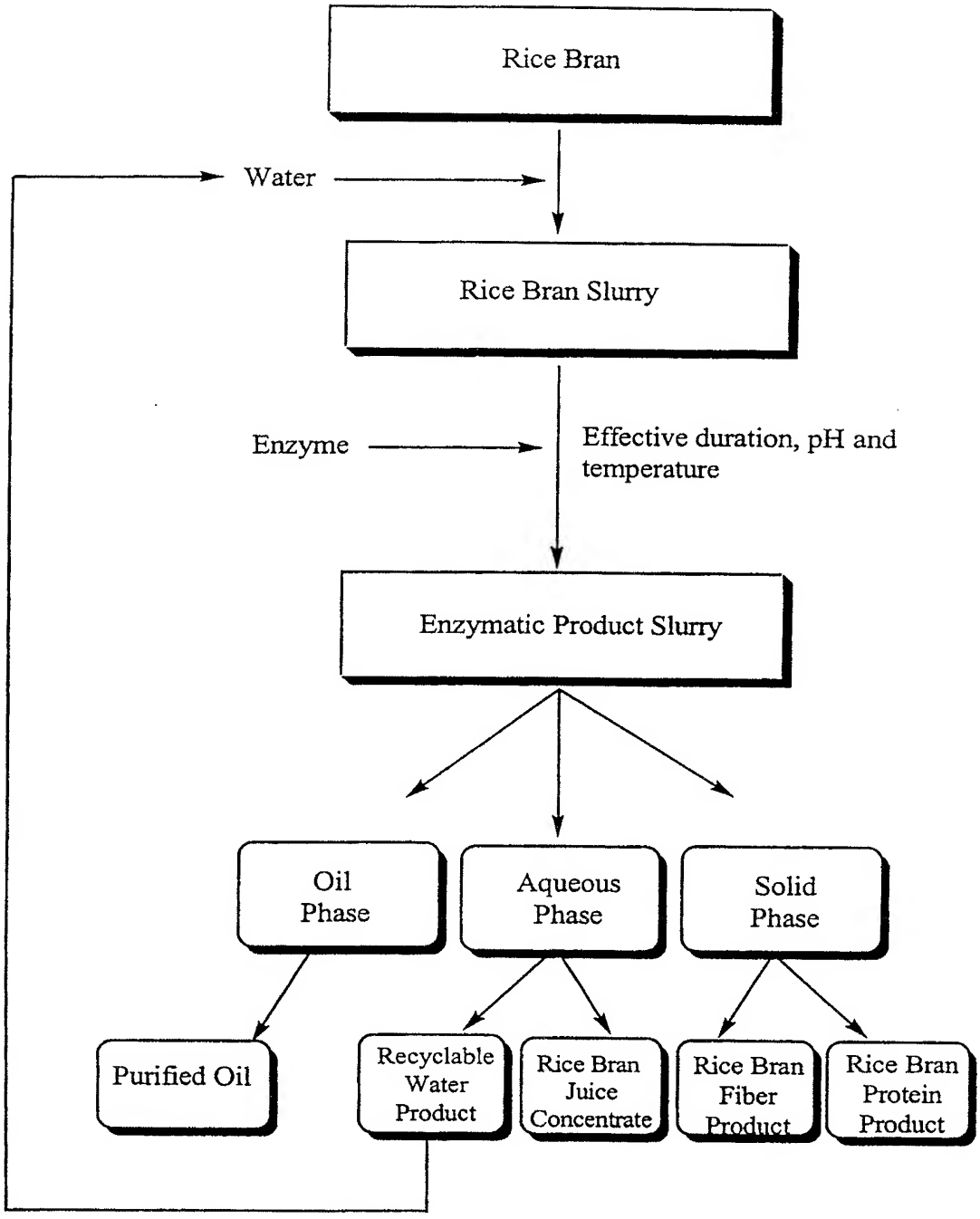
38. The process of claim 4, wherein the rice bran protein product represents at least about 10% of total protein content of the rice bran.

39. The process of claim 3, comprising treating the rice bran juice concentrate with an isoelectric precipitation procedure.

40. The process of claim 3, comprising treating the rice bran juice concentrate with an alkali solubilization procedure and an isoelectric precipitation procedure.

41. The process of claim 4, comprising an alkali solubilization procedure and an isoelectric precipitation procedure.

42. The process of claim 40 or 41, wherein the alkali solubilization procedure is performed at a pH of about 11 to about 12, and the isoelectric precipitation procedure is performed at a pH of between about 4 and about 5.


Rice Bran
Water
Rice Bran Slurry
Enzyme
Effective duration, pH and temperature
Enzymatic Product Slurry
Oil Phase
Aqueous Phase
Solid Phase
Purified Oil
Recyclable Water Product
Rice Bran Juice Concentrate
Rice Bran Fiber Product
Rice Bran Protein Product

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/04607

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :A23L 1/36
US CL :426/44, 50, 51, 52, 495
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 426/44, 50, 51, 52, 495

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WEST, DIALOG
search terms: rice, rice bran; oil, solid and aqueous phase, extract$, slurry, pectinase, cellulase, hemicellulase.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,904,483 A (CHRISTENSEN et al.) 27 February 1990, see entire document.	1-42
Y	US 6,015,840 A (NAKAMURA et al.) 18 January 2000, see entire document.	1-42
Y	US 5,288,619 A (BROWN et al.) 22 February 1994, see entire document, especially col. 2, and col. 9-17.	1-42

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"B" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 MAY 2001	12 JUN 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer KEITH D. HENDRICKS Telephone No. (703) 308-0661

Form PCT/ISA/210 (second sheet) (July 1998) ★